WOODS HOLE OCEANOGRAPHIC INSTITUTION
Department of Physical Oceanography
Woods Hole, MA 02543

James F. Price, 508-548-1400 (x 2526)
Omnet: J.Price.WHOI, Internet: jim@buckwheat.whoi.edu, Fax: 508-457-2181

December 15, 1993

Dr. Steve Ramp
ONR

RE: Final Report on N00014-89-J-1053

Dear Steve;

This is the final report on my grant to study the Mediterranean outflow. The major activity during the grant period was a field experiment carried out in fall 1988 in collaboration with Tom Sanford and Rolf Lueck. We made a detailed survey of the Mediterranean outflow in the Gulf of Cadiz, with special emphasis on the regions where the outflow mixes most rapidly with the overlying North Atlantic water. This new data set gave an unprecedented view of the dynamics of a marginal sea outflow. An overview of the results was reported in a major article in SCIENCE (copy enclosed), and a very detailed analysis was given by Molly Baringer in her WHOI/MIT PhD thesis entitled 'Mixing and dynamics of the Mediterranean outflow'. This grant supported Molly during much of her PhD work.

A second major effort was to develop models of marginal sea outflows, the results of which are in a paper that has been accepted to Progress in Oceanography (copy enclosed). This paper dealt with the four major outflows that supply new water to the thermohaline circulation, and provides considerable insight into the dynamics and possible climate consequences of these outflows. The next steps in the modelling work (unfunded at present) are to develop 3-D models of outflows and to learn how to include outflows within the framework of GCMs.

In all, this has been the most productive single grant I have ever had and the collaboration with Sanford and Lueck has been extremely fruitful (Tom has kept a log of contributions from our joint work on the Gulf of Cadiz project and the last I knew the count was up to more than 35 !).

If you would like to have a seminar on the topic of outflows or deep water formation I would be delighted to come down and tell you what we have learned. The topic is inherently interesting, and our project is a very nice example of the interplay between theory and observations.

Best Regards,

Jim Price

Jim Price

cc: L. Goodman (1)
R. Tanner (a)
Director, Naval Research Laboratory (6)
Devense Technical Information Center (12)

Reprint Series
26 February 1993, Volume 259, pp. 1277–1282

SCIENCE

Mediterranean Outflow Mixing Dynamics

James F. Price,* Molly O'Neil Baringer, Rolf G. Lueck, Gregory C. Johnson, Isabel Ambar, Gregorio Parrilla, Allan Cantos, Maureen A. Kennelly, and Thomas B. Sanford

Outflows

James F. Price and Molly O'Neil Baringer
Woods Hole Oceanographic Institution
Woods Hole, MA, 02543

August 3, 1993

Abstract

We examine some of the processes that determine the properties of marginal sea outflows by reviewing historical data on the four major outflows (Mediterranean Sea, two from the Norwegian-Greenland Sea, and Weddell Sea) and by an analysis of numerical simulations. Our simulation model makes several of the streamtube approximations of Smith (1975), but goes on to include Froude number-dependent entrainment, a parameterization of broadening due to bottom drag, and real bottom topography and oceanic temperature and salinity profiles. This model reproduces some of the main features of these outflows, including the localized character of strong mixing, and the density reordering of source and product waters.

The simulated Mediterranean outflow is initialized at the west end of the Strait of Gibraltar (Θ = 13.4 C and S = 37.9 pss) and then descends into the Gulf of Cadiz along a path determined by the model's dynamics and by the topography. Within the first 50 km the outflow descends about 250 m and accelerates to a maximum speed of about 1.2 m s^{-1}. This raises the Froude number above 1, and causes strong entrainment of fresher, overlying North Atlantic Central Water (NACW). Entrainment more than doubles the volume transport of the outflow, and reduces the temperature and salinity to 12.3 C and 36.45 pss which reduces the density by about 1 kg m^{-3}. Entrainment stops where the Coriolis force turns the